

# Designing coherent flight-deck procedures for use in advanced technology aircraft

*Flight crews are more likely to conform with the standard operating procedures when the designers create a set of procedures that are both logical and consistent.*

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A HUMAN-MACHINE system is not merely one or more human operators and a collection of hardware components: in order to operate a complex system successfully, the human-machine system must be supported by an organizational infrastructure of operating concepts, rules, guidelines and documents. The consistency and logic of such operating concepts is vitally important for the efficiency and safety of any complex system.

In high-risk endeavours such as aircraft operations, it is essential that such support be flawless, as the price of deviations can be high. When operating rules are not adhered to, or the rules are inadequate for the task at hand, not only will the system's goals be thwarted, but there may be tragic human and material consequences.

To ensure safe and predictable operations, support to the pilots often comes in the form of standard operating procedures (SOPs). These provide the crew with step-by-step guidance for carrying out their operations. SOPs do indeed promote uniformity, but they do so at the risk of reducing the

role of human operators to a lower level.

Management must recognize the danger of relying excessively on procedures, an approach that fails to exploit one of the most valuable assets in the system, the intelligent operator who is "on the scene." The alert system designer and operations manager recognize that there cannot be a procedure for everything, and the time will come in which the operators of a complex system will face a situation for which there is no written procedure. Procedures, whether executed by humans or machines, have their place, but so does human cognition.

A dramatic example was provided by an accident at Sioux City, Iowa in 1989. A United Airlines DC-10 suffered a total loss of hydraulic systems, and hence aircraft control, because of a disintegration of the centre engine fan disk. When the captain had sized up the situation, he turned to the flight engineer and asked what the procedure was for controlling the aircraft. "There is none," replied the engineer, a point that is worth remembering. Human ingenuity and resource management were required; the crew used unorthodox methods to control the aircraft. This resulted in a crash landing in which over half the passengers survived.

## Procedural deviation: its influence on safety

In 1987 researchers at Boeing conducted a study of jet transport accident reports in order to "better understand accident cause factors." They analysed 93 hull-loss

accidents that occurred between 1977-84. The leading crew-caused factor in their study was "pilot deviation from basic operational procedures."

The potential for a procedural deviation leading to a fatal accident can be seen from three airline accidents that occurred during a three-year period. In the first, Northwest Airlines Flight 255, a McDonnell Douglas MD-82, crashed at Detroit Metropolitan Airport in 1987 while attempting to take off without having extended wing flaps or slats to the take-off position. In 1988, Delta Air Lines Flight 1141, a Boeing 727, crashed shortly after lifting off from Dallas-Fort Worth International Airport without first deploying the flaps or slats. In 1989, USAir Flight 5050, a B-737, ran off the runway at La Guardia Airport and dropped into adjacent waters, following an error in the setting of the rudder trim and several other problems.

## NASA study methodology

Three major U.S. airlines, which had previously expressed an interest in evaluating the way in which procedures are designed, agreed to participate in a study on the use and design of flight-deck procedures undertaken by the authors for the U.S. National Aeronautics and Space Administration (NASA) Ames Research Center. The authors visited each of the three airlines to conduct interviews with flight management and line pilots, observe flight operations in over 200 legs in the jump seat, and attend procedure design meetings. The research focused on procedures for automated cockpits (e.g. B-757/767, A320, B-737-300).

## A model for procedure development

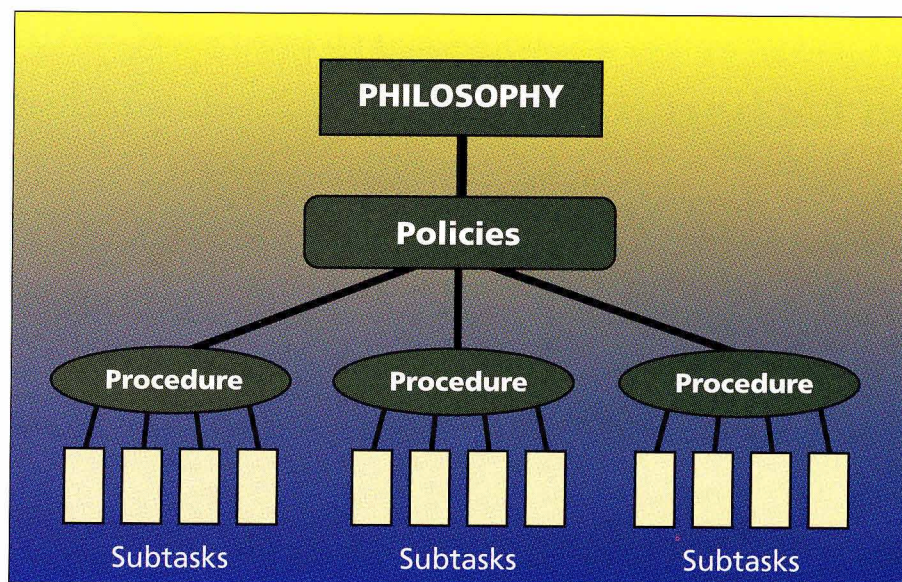
Procedures are not inherent in the equipment. Procedures must be based on a broad concept of the user's operation. These operating concepts blend into a set of work policies and procedures that specify how to operate the equipment efficiently. There is a link between procedures and the concepts of operations. We call that link the three "P's" of cockpit operations:

## NASA REPORT

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Copies of the report can be obtained from Asaf Degani; requests should be addressed to MS 262-4, NASA Ames Research Center, Moffett Field, CA 94035-1000, United States. A copy can also be accessed via the Internet from the following worldwide web (www) site: <http://olias.arc.nasa.gov/publications/online-publications.html>.





**The three "P's" of cockpit operations. Adherence to this model leads to a higher degree of conformity to procedures during line operations.**

*philosophy, policies, and procedures.* After exploring how an orderly, consistent path can be constructed from the company's philosophy of operation to the actual conduct of any given task, we'll focus on what we call the fourth P — *practices*.

### Philosophy

The cornerstone of the three P's model is an organization's philosophy of operations. By philosophy we mean the airline management's over-arching view of how the business of the airline, including flight operations, is to be conducted. A company's philosophy is largely influenced by the individual philosophies of the top decision makers. It is also influenced by the company's culture, a term that has come into favour in recent years to explain broad-scale differences between corporations. The corporate culture permeates the company, and a philosophy of flight operations emerges.

The emergence of flight-deck automation has recently generated an interest in the philosophy of operations, partly due to lack of agreement about how and when automatic features are to be used, and who may make that decision. This led one air carrier, Delta Air Lines, to develop a one-page, formal statement of automation philosophy. Subsequently, other airlines developed similar statements.

### Policy

The philosophy of operations, in combination with economic factors, public relations campaigns, new generations of aircraft and major organizational changes, generates policies. Policies are broad spec-

ifications of the manner in which management expects things to be done (training, flying, maintenance, exercise of authority, personal conduct, etc.). Procedures, then, should be designed to be consistent as much as possible with the policies (which, in turn, should be consistent with the philosophy). The accompanying figure depicts this framework.

### Procedures

In general, procedures exist in order to specify, unambiguously, six things: (1) what the task is; (2) when the task is conducted (time and sequence); (3) by whom it is conducted; (4) how the task is done (actions); (5) what the sequence of actions consists of; and (6) the type of feedback that is provided (call-out, indicator).

The function of a well-designed procedure is to aid flight crews by dictating and specifying a progression of subtasks and actions to ensure that the primary task at hand will be carried out in a manner that is logical, efficient and also error resistant. Another important function of a cockpit procedure is that it should promote coordination between agents in the system, be they cockpit crew, cabin crew, ground crew or others. In most high-risk industries, procedures come packaged as standard operating procedures. So strong is the airline industry's belief in SOPs, that

it is believed that in a well standardized operation it would be possible to replace a cockpit crew member in mid-flight with another qualified pilot and have the operation continue safely and smoothly. Nevertheless, any human operator knows that adherence to SOPs is not the only way that one can operate equipment. There may be several other ways of doing the same task with a reasonable level of efficiency, logic and safety.

To illustrate application of the three P's, let us assume that the task at hand is the configuration of an advanced technology aircraft for a Category-I ILS approach:

- **Philosophy.** Automation is just another tool to help the pilot.

- **Policy.** The use or non-use of automatic features (within reason) is at the discretion of the crew.

- **Procedure.** On a Category-I approach, the flight crew will first decide what level of automation to use (i.e. hand-fly with flight director, autopilot and mode control panel coupled, etc.), which determines what must be done to configure the cockpit.

- **Subtasks (or actions).** These follow from procedures (e.g. tune and identify localizer and compass locator, set decision height, select autopilot mode, etc.).

In some cases, remote policies that are unrelated to flight operations can affect procedures. One air carrier's new public relations policy called for the captain to stand at the cockpit door as passengers departed the cabin. In particular, the marketing department wanted the pilot to be in place at the cockpit door in time to greet

the disembarking first-class passengers. This dictated a procedural change in that most of the secure-aircraft checklist had to be done alone by the first officer. Thus checklist procedures which would normally be performed by both pilots, probably in the form of challenge and response, were performed by a single pilot in deference to public relations imperatives.

We argue that if philosophies and policies are articulated, then (1) a logical and consistent set of cockpit procedures that are in accord with the policies and philosophy can be generated; (2) discrepancies and conflicting procedures will be easily detected; and (3) flight crews will be aware of the logic behind every SOP.

**In some cases, remote policies unrelated to flight operations can affect procedures.**





*To address such questions as how and when automatic features on the flight deck are to be used, Delta Air Lines developed a formal statement of automation philosophy; other air carriers have since developed similar statements. McDonnell Douglas photo*

We believe that adherence to the three-P model will lead to a higher degree of conformity to procedures during line operations.

#### **The fourth "P"**

The model, up to this point, provides a framework for the development of procedures. Yet it is incomplete. It overlooks the pilot, for whom procedures are designed. To correct this oversight, we have added an additional component — practices. This term encompasses every activity conducted on the flight deck. While a procedure may be mandatory, it is the pilot who will either conform or deviate from it. The deviation may be trivial (e.g. superimposing some non-standard language on a procedural call-out), or it may be significant (e.g. not setting the auto-brakes according to the take-off procedure). Ideally, procedures and practices should be the same.

#### **The influence of automation**

Automation makes it more difficult to mandate a large set of stringent procedures. Several factors lead to this.

(1) Since most modern automation is controlled by a digital processor, the interface between human and machine is usually some form of computer input device. The most common form is a keyboard. Using the computer, simple tasks, such as loading the flight plan, can be performed somewhat as a set of procedures. Nevertheless, tasks that must be conducted in real time require far more complex interaction with the computer, and hence cannot be defined by a simple set of procedures. In order to

overcome this, pilots develop their own techniques.

(2) Many aircraft systems, such as the autoflight system, operate in a dynamic and sometimes unpredictable environment and therefore cannot be completely pre-programmed. In these cases, the autoflight system provides the pilot with several semi-automatic modes from which to choose. For example, there are at least five different modes by which the autoflight system can change the aircraft's altitude. Therefore, any attempts to apply a set of procedures to such tasks by mandating one method would usually fail (and lead to non-compliance). One major U.S. company attempted to use an SOP for the descent profile of its B-737 glass cockpit fleet. The result was non-compliance. The procedure was quietly abandoned.

To conclude, a procedure that is ponderous and is perceived as increasing workload or interrupting the smooth flow of cockpit tasks will probably be ignored. Even worse, there could be a spread of this effect, since a violated procedure may lead to a more general distrust of procedures, resulting in non-conformity in other areas.

#### **Technique**

Technique is the superimposition of a pilot's own way of completing a procedure.

The use of technique allows the pilot to express individualism and creativity without violating procedural constraints. If the technique is consistent with the procedure and the overlying policy, the task is conducted with no violation of constraints.

Techniques have been developed by

pilots over their years of experience of flying various aircraft. Every pilot carries with him a virtual catalogue of techniques, often fine points which he has himself discovered, experimented with or learned from other pilots. Why does the procedure writer not include the techniques as part of the procedure? Generally this is not advisable: the techniques are too fine-grained. If SOPs included the detailed descriptions necessary for one to carry them out, the flight operations manuals would be many times their present size.

#### **Conclusions**

Flight-deck procedures are the backbone of cockpit operations. They are the structure by which pilots operate aircraft and interact with other agents in the system. It was traditionally believed that procedures are totally software and hardware dependent, and that they are inherent in the device. We have attempted to demonstrate that they are also dependent on the operational environment, the type of people who operate them, the company culture and the nature of the company's operations. Procedures are not inherent in, or predictable from, any single entity. □

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